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Special Issue: Energy Poverty Varieties

Title: Energy periphery: uneven development and the precarious geographies of low-carbon transition

Oleg Golubchikov[1,2] and Kate O'Sullivan[1]

[1] School of Geography and Planning, Cardiff University, Cardiff, UK
[2] Visiting Professor, National Research University Higher School of Economics, Moscow, Russia

Corresponding author: Oleg Golubchikov
Email: GolubchikovO@cardiff.ac.uk
Address: School of Geography and Planning, Cardiff University, Glamorgan Building, King Edward VII Avenue, Cardiff, CF10 3WA

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Abstract
The paper introduces the concept of energy periphery to interrogate place-based perspectives on the co-production of uneven geographical development, energy vulnerabilities and low carbon transitions. Energy periphery is defined as places that are systematically disadvantaged through the whole energy system due to their inferior position within the asymmetrical spatial distribution of material, economic, political and symbolic resources and capabilities. Within an energy periphery, energy-related factors are combined with other place-based conditions to subject their communities to a compound and circular effect of precarious energy experiences. The notion of energy periphery is underpinned by insights from the spatial justice, core-periphery and energy justice theories. Using the case of Wales, the paper demonstrates the multi-dimensional and multi-scalar character of energy peripheralization, including political underrepresentation, the absence of economic agglomeration advantages, and dependence on off-grid fuels, energy inefficient homes and other 'backward' technologies and practices. Social and spatial contingencies of end-use energy vulnerability factors are outlined. Contrary to common discourses, energy transition further disadvantages energy peripheries and reproduces a fragmented socio-spatial landscape. The study overall demonstrates the importance of considering energo-socio-spatial relationships to better understand uneven energy transitions and social change more generally.

Keywords
Spatial justice; energy justice; energy deprivation; fuel poverty; energy vulnerabilities; energy transition; uneven development; core and periphery; Wales; the United Kingdom

1. Introduction

The imperative of energy transitions is well rehearsed in policy and academic literature – including from the sociotechnical perspectives that currently dominate social sciences' view of transition (Geels et al. 2016). Within the now-substantial 'transitology' literature, there is also a growing body of studies that acknowledges the importance of (fluid) geographical factors underpinning and differentiating energy systems and energy transitions, including the role of regional and local conditions and dynamics, as well as specific socio-spatial formations (e.g. Bridge et al. 2013; Balta-Ozkan et al. 2015; Hansen and Coenen 2015; Bouzarovski et al. 2017; Solomon and Calvert 2017; Castán Broto and Baker 2018; Yenneti et al. 2019). This literature has allowed shifting away from ontologies that presume spatially-blind centrifugal diffusion of energy transition and develop a more nuanced understanding of the varied articulation of place-based effects of transition: to see how transition negotiates itself through place-contingent conditions, endowments, planning and governance regimes, everyday practices, as well as indigenous experimentations and innovations.

What gradually emerges from this literature (albeit often implicitly) are relationships between energy transition and exigencies of uneven geographical development. The latter can be seen as a multi-scalar process of the production and reproduction of spatial inequalities and injustices constituted by physical, historical, cultural, economic and political conditions (Smith 1990; Harvey 1996; Soja 2009). Such inequalities form the contexts and preconditions within which energy transitions are happening, influencing places' differing ability to engage with energy projects and innovations (Baker and Mehmood 2015). For example, despite the promise of more inclusive energy systems, for local communities with a deprived capacity to act or a high concentration of low-income households, the experiences of transition may be more toxic than beneficial: such communities often merely subsidise transitions happening elsewhere through their energy bills (Bickerstaff et al. 2013) or are used for the location of externally owned and controlled renewable energy projects, which can often have detrimental consequences for the local life, such as displacement, dispossession or exclusion (Cowell et al. 2012; Baka 2013; Yenneti et al 2016; Avila 2018). The process of low-carbon transition may thus be reifying instead of rectifying the pre-existing injustices (Sovacool et al. 2019a). Furthermore, many localities will be vulnerable to new energy modalities due to their pre-existing energy mix, industries, infrastructures, built forms, or socio-economic factors (While et al. 2010). This complexity necessitates moving beyond the linear multi-win assumptions underlying the deployment of low-carbon policies to a more nuanced understanding of the processes pertaining to actually existing *energo-socio-spatial transitions* (Golubchikov and Deda 2012).

In this paper, we seek to contribute to this intellectual call by articulating the co-production of energy vulnerabilities and geographical *peripheralization*, resulting in particular energo-socio-spatial relationships: energy periphery. The division between core and periphery is one of the key dimensions in the dynamics of uneven geographical development and yet it is little explored in relation to energy transition, especially at a sub-national or sub-regional level (Murphy and Smith 2013). Current studies' usage of periphery regarding energy systems is ambiguous and taps mostly into the concept of resource periphery, understood as regions rich in natural resources but located outside the economic core (e.g. Hayter et al 2003), or, oppositely, employs energy periphery as a descriptor for regions lacking energy resources. We will want to provide a sharper view, which is not limited to a resource economy *per se*, but encompasses a broader politico-economic perspective of peripheralization as part of the social production of space and uneven distribution of power. We therefore introduce the notion of energy periphery, by which we understand places (regions, communities) which are systematically disadvantaged through the entire energy system (including energy generation, distribution and consumption) due to their inferior position within the asymmetric spatial distribution of political, economic and symbolic capabilities.

We ground our study in the context of Wales, which already can be considered as a peripheral nation within the UK (Keating and Jones 1991; Owen et al. 2000). Yet, Wales internally consists

of its own relative centrality and peripherality. In a common discourse on socio-economic development, peripheral places in Wales are those that have limited access to services and employment opportunities and include small settlements or sparsely populated areas, distal from larger urbanised centres and often experiencing inter-generational problems of social deprivation (Heley et al. 2011; Kitchen 2012). This is not necessarily dissimilar from the politico-economic understanding of periphery, which we employ, including with regard to the geographically uneven relations of control over economic assets and development, resulting in the periphery's chronic dependency on the core. Our field research focussed on such areas in South Wales. We conducted over 30 semi-structured interviews with households, in addition to a similar number of expert interviews with community groups, third sector, governance institutions, and energy related experts. This range of interviews, taking place in 2016-2019, encompassed the local authority areas of Carmarthenshire, Merthyr Tydfil, Monmouthshire, Neath Port Talbot and Powys, as well as pan-Wales and broader perspectives. Household interviews focused on the context and place that the householders lived; their past and present energy needs, access, costs and experiences; and their engagement with low-carbon energy transition. Expert interviews were tailored to specific organisations or individuals and their involvement with the problematic of energy generation, energy efficiency, fuel poverty and transition. We also considered contextual data such as fuel poverty designations, access to energy networks, income levels, demographic composition, as well as building structure and energy efficiency ratings.

What has emerged from these data – and what we discuss later in the paper – are peculiar energy experiences, including experiences of energy transitions, for those who live in those remote areas. Being associated with such areas is a structurally significant factor for manifesting energy vulnerability. This is not merely due to the concentration of low-income people in these areas, although this is one of the important compound elements; but this is also due to the nature, status and limitations of local energy systems (e.g. many residents depend on off-grid fuels), housing conditions (e.g. a large proportion of poorly insulated homes), mobility and accessibility requirements (reliance on cars, frequent disruptions in fuel delivery), as well as, crucially, due to the more general circumstances of economic and political marginalisation of these areas – including with respect to a low priority for energy and public infrastructure development, austere public services, weak economic and employment bases, and a lack of agency in energy-related decision-making. In other words, in addition to generic (and well-explored) household-level vulnerabilities (social contingencies), energy vulnerabilities in such areas emerge from within, and as an inseparable part of, the bigger web of peripheral structural disadvantages, many of which are distinctive, if not unique, to the conditions of peripherality. These socio-spatial contingencies of peripheral energy vulnerabilities will be encapsulated in our notion of energy periphery.

The rest of the paper is structured as follows. The next section develops our conceptual matrix – the interplay of uneven development, spatial justice and energy vulnerabilities – in order to further outline our framework for energy periphery as a form of energo-socio-spatial relationships. Following on from that, we discuss socio-economic vulnerabilities related to peripheral disadvantage and their interplay with energy conditions in Wales. We also demonstrate how peripheralization creates a fragmented landscape of low-carbon transition. Our broader ambition is to highlight that socio-technical transitions are not place-neutral but part of spatially contextualised and uneven energy landscapes (cf. Bridge et al. 2013).

2. Conceptualising energy periphery

2.1.Spatial justice, energy and peripheralization

One way to approach energy periphery is through the lens of spatial justice and energy justice. These two strands of ideas are informed by moral philosophy and are derivatives from the theories of social justice, which search for fairness in social order (Rawls 1971). Thus, spatial justice seeks

to understand the spatially contingent mechanisms that underlie power relations and struggles, social inequities and uneven development (Soja 2009), while energy justice has offered a critical framework to explore factors that contribute to the distribution of costs, benefits, vulnerabilities and influences relating to energy systems (Heffron et al. 2015; Sovacool and Dworkin 2015; Jenkins et al. 2016). Both strands of thoughts were influenced by developments in environmental justice that hold similar concerns over uneven environmental impacts (Agyeman and Evans 2004; Bulkeley and Walker 2005; Walker 2012; Schlosberg 2013). However, despite their shared roots and intellectual pursuit, there still remains surprisingly little explicit dialogue between energy justice and spatial justice. Recent attempts to fill that gap are important (Yenneti et al. 2016; Bouzarovski and Simcock 2017) but need to be refined both conceptually and empirically. Below we consider how exchange between energy and spatial justice, as well as between them and related hosts of ideas (uneven development, core-periphery, energy vulnerabilities), can help articulate the notion of energy periphery that is centred on the relationships between spatial, social and energy conditions (or energo-socio-spatial relationships).

To begin with, studies in spatial justice unpack dynamics behind socio-political organisation of space and spatial inequalities and inequities, including relating to the location of social goods and bads, access to employment, education, infrastructure, public services and other socially valued resources. In this tradition, spatial categories and divides are seen not as incidental but a product of their reciprocal relations with politics, economics and culture. In other words, space is socially produced – in the sense that space is given its meaning and value through social processes and institutions and, as such, space itself becomes a constitutive factor in ordering social processes and relations (Lefebvre 1991; Harvey 1996; Massey 2005; Soja 2009). As political, economic and cultural resources and forces are unevenly distributed, spatialization is also uneven and power-laden and creates experiences of dependency and domination, exploitation and marginalisation. From the perspective of spatial justice, uneven development and other circumstances whereby some places are advantaged over the others are seen as a form of injustice.

Many such spatial injustices of power struggles and uneven development are energy-related, as evident in conflicts and uneven distribution of benefits and costs over energy developments, both historically and contemporary. The energy-environmental contestations (e.g. Martinez-Alier 2001; Martinez-Alier et al. 2016) have been explored, for instance, in relations to coal mining (Milbourne and Mason 2017), fracking (Holifield and Day 2017), biofuels (Baka 2013), wind (Cowell et al. 2012), solar (Yenneti et al. 2016) and many other energy types and projects. These studies demonstrate not only social contradictions in such developments, but essentially spatial conflicts where already less privileged place-based communities experience systematic disbenefits or harms as a result of local environmental damage and pollution or are exposed to land grab and direct displacement and dispossession. Studies in environmental justice also demonstrate how energy developments, emanating from distant decision-making centres, may turn some places into ‘sacrifice zones’ enabling the common good for the ‘greater whole’ but essentially marginalizing those places and their populace (e.g. Holifield and Day 2017; Hernandez 2015). Such considerations of spatial and environmental justice bring us more closely to our concern with the construction of periphery as a spatiality that is ‘inferior’ to the core.

The nature of core-periphery relationships has been addressed by many studies, influenced, among others, by Myrdal’s (1957) cumulative causation theory, Frank’s (1969) dependency theory, Wallerstein’s (1979) world systems, and Krugman’s (1991) new economic geography (which expands from the economics of externalities and agglomeration). Most of these ideas maintain that development and underdevelopment may be cumulative and self-perpetuated, leading to virtuous and vicious circles: for example, growth in one area will lead to labour, skills and infrastructure being pulled away from less successful areas so that over time “qualitative as well as quantitative differentiation between places within those socio-spatial structures” may increase (Hudson 2015, p. 25). Copus (2001) suggests considering three groups of elements making peripheries – causal, contingent and associated. *Casual elements* include, for example, “increased travel and transport costs”, which can be seen as “the tyranny of distance” (Copus 2001, p. 541) – we can also say

transaction costs – representing additional costs that may deter businesses from investing in peripheral areas, thus making core areas all the more attractive for investment. There is also the "absence of agglomerative advantage" (Copus 2001, p. 540), such as markets, demand and labour pool. *Contingent elements* include higher costs of service provisions and low levels of new business development and innovation. Finally, *associated elements* include sparse populations, dependence on primary industries, poor infrastructure and poor political representation.

However, while these – formalist – insights are useful in analysing the existing manifestations of disparity between core and periphery, it is still the critical tradition rooted in Marxist geography (the same tradition that also produced the spatial justice theory) that seeks to understand the more fundamental root-cause of uneven development as "the systematic geographical expression of the contradictions inherent in the very constitution and structure of capital" (Smith 1990, p. 4). Here, the configurations of spatial injustice and uneven development, like those of space more generally, are understood to be the product of the dominant politico-economic system and social relations specific to that system (Harvey 1996). Thus, under capitalism, the *production* of uneven development is seen inherent to capitalism due to its concentration and centralisation tendencies in the accumulation of capital, restless profit-seeking in Schumpeterian creative destruction, requiring investment and disinvestment in different areas (Smith 1990), but also due to its requisites for the spatial division of labour (Massey 1995). Our own previous studies demonstrate how the introduction of the market economy in the hitherto non-capitalist (and yet economically advanced) spatialities such as formerly socialist regions can quickly transform the landscape of relative equality into the structurally uneven spatial development of 'success' and 'failure' – most vividly demonstrating that uneven development is a product of politico-economic modalities rather than a 'naturally' occurring condition of differentiation (Golubchikov et al. 2014; Golubchikov 2016).

Furthermore, while core and periphery may be shaped by the logics of capital and agglomeration, it is underpinned culturally, as it is cultural conditions that create meaning that society attaches to different places (Harvey 1996; Massey 2005). Economically peripheral places – places that are underdeveloped and lacking control over economic assets – are usually also symbolically peripheral. These differences are reinforced via political rhetoric and media representations from a core perspective, further solidifying the divides. Thus, peripheries are likely to experience social, economic and political marginalization, with less power to influence decisions over resource access and allocation. Overall, peripheralization can be understood as "a spatially organized inequity of power relations and access to material and symbolic goods that constructs and perpetuates the precedents of the centre over the marginalized" (Fischer-Tahir and Nauman 2013, p. 18).

2.2. Energy peripheries

Energy systems often underpin such peripheralization processes (Pasqualetti and Brown 2014). In the UK, for example, the structure of energy networks, which developed due to industrial demand, persists, with energy networks usually denser in core and urban areas so that they may be used to their maximum potential and profit (Soja 2010). This also affects differential access to type and price of fuel between core and periphery. For sparsely populated areas, there is limited access to mains gas supplies and thus less competitively priced and more limited choices of fuel (Office of Fair Trading 2011) compounding to energo-social vulnerabilities. However, the density of energy distribution and consumption network may contrast with the position of periphery as part of production. Milbourne and Mason (2017) highlight that the same peripheries have for many years been exploited for their national resources, such as water, wood and carbon-heavy resource extraction required for traditional energy production, with little concern over environmental and socio-economic impacts. This fits well with conceptualisations of "resource peripheries" (Hayter et al. 2003, p. 17); these are places of relatively weak economic, social and political power, vulnerable to dependence on external core investment and thus having limited choice over industrial development and diversification. While peripheries supply what the core needs, greater

economic benefits are retained in core places where ownership of higher value outputs such as technical supply chains and R&D are preserved. Here, peripheral communities are rendered vulnerable all round, through the entire energy system, despite their possible position as a resource supply.

The ideas of peripheralization can thus be extended to the experiences and causalities of energy vulnerability. The concept of 'energy vulnerability' is one of key considerations within energy justice (Bickerstaff et al. 2013; Middlemiss and Gillard 2015). Contrary to the policy-laden fuel/energy poverty terminology, energy vulnerability in a broader academic discourse is an intellectually more inclusive category in the sense that it "does not imply a particular emphasis or understanding of cause and effect" as a fixed outcome (Day and Walker 2013, p. 16); rather it conveys more dynamic energy-related conditions that may put households' wellbeing at risk. These conditions may lead to circumstances where "a person or household is unable to achieve sufficient access to affordable and reliable energy services, and as a consequence is in danger of harm to health and/or wellbeing" (Day and Walker 2013, p. 16). The situations of vulnerability and the harm in the form of energy deprivation are dependent on how specific spatial, socio-economic, demographic, cultural and institutional dimensions co-align (Kuhlicke et al. 2011). Such an energy vulnerability lens can help understand how different contextual elements, including those spatially derived, can influence energy deprivation. However, the literature on energy vulnerability is currently end-use centric, focusing on the socio-economic position of particular social groups or individuals. This generally holds limited explanation as per how energy vulnerabilities are constituted at multiple scales and relationally, in interplay with other social and technical vulnerabilities, including those that are spatially contingent (Bouzarovski and Simcock 2017). A whole energy system approach and place-based perspectives can fill this gap in energy vulnerability literature (Hernandez 2015; Jenkins et al. 2016) - which necessary brings energy vulnerability more closely to the considerations of uneven development and core-periphery.

The notion of energy periphery can then be outlined based on the nexus of energy, periphery and vulnerability. We define energy periphery as place-bound conditions of systematic vulnerabilities and disadvantages experienced by some communities through the entire energy system due to their non-core position within the spatially asymmetrical distribution of political, material, economic, symbolic and other resources and capabilities. While not all places that are commonly referred as peripheral merely due to their physical remoteness can be seen as energy peripheries, the majority of 'socio-political peripheries' *are* energy peripheries at the same time. This is not a coincidence. Figure 1 furthers our definition above and represents energy periphery as a web of mutually-reinforcing factors, both energy-related and socio-economic. It identifies that elements of peripheral disadvantages and energo-social vulnerabilities are interlinked in numerous and messy ways: the presence of each, either singularly or in constellations, holds impacts for the others, including the reinforcement of their presence.

We acknowledge that all complexities cannot be reduced to simple classes; nonetheless such conceptualisation is important to highlight broader trends. Here, energy periphery offers a steady focus on certain structural spatial forms of energy vulnerabilities exacerbated by peripheral disadvantage. Certainly, not all peripheral places experience energy-related disadvantages, nor do energy-vulnerable peripheries have the monopoly for concentrating such vulnerabilities – the latter are manifested among many residents within the core too, such as in metropolitan areas. But energy periphery reveals how place-bound disadvantages in certain areas that are already marginalised (peripheralised) in the dominant politico-economic systems are further articulated with, and articulate, a vulnerable position in the energy system and produce a whole distinctive and systematic class of energy inequities. As we will demonstrate later in this paper, to belong to an energy periphery is a recipe for energy precarity, if not deprivation. The lens of energy periphery also reconciles the paradox that the 'burden' of primary energy production lies predominantly with the periphery but the same periphery may still experience energy precarity. Peripheries with the availability of natural resources for energy generation are the least problematic locations for new energy projects, but profits extracted from such projects as well as the orientation of the distributing

infrastructure gravitate towards high-consuming places with their economy of scale. As we further demonstrate below, the knowledge of such place-based situations is important also because it helps to better understand (uneven) energy geography and (fragmented) landscapes of transition.

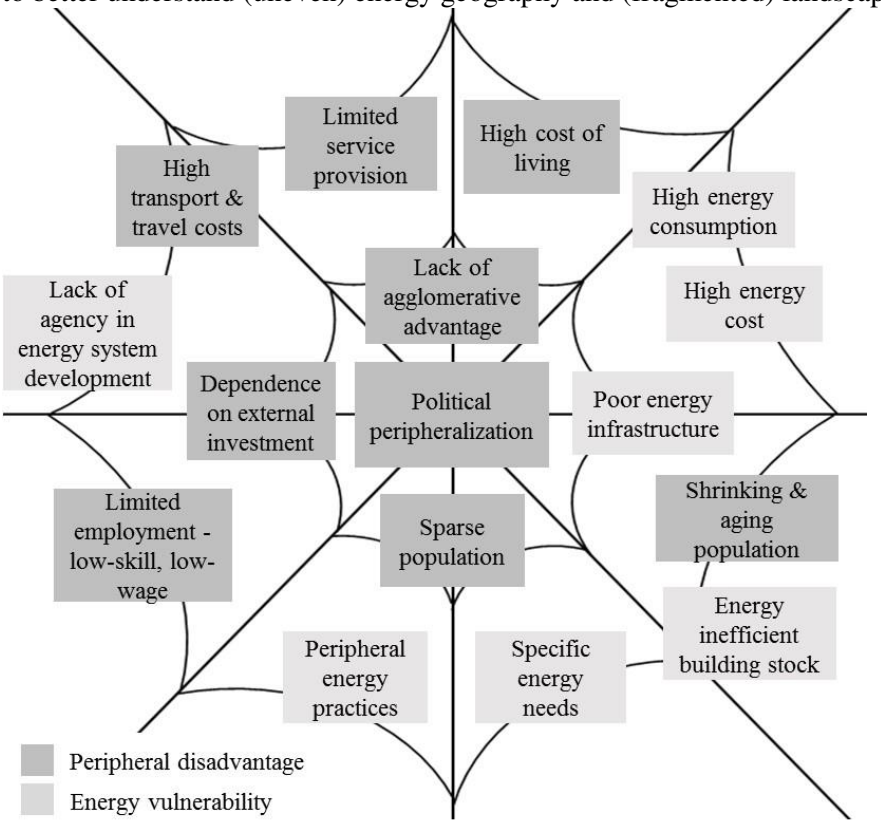

Figure 1. Energy periphery as a web of spatial, social and energy disadvantages

2.3.Energy periphery in low carbon transition

Of course, low carbon transition is transforming the extant energy system. More than a change in sources of energy, transition is altering spaces of resource extraction, production, distribution and consumption, thus disrupting social, economic and political arrangements (Laird 2013), for example, transforming the role of traditional consumer to energy producers or "prosumers" (Szulecki 2018, p. 21). Alternative and varied scale ownership models allow for variations in the price of energy and for alternative investment routes for economic profits. In the case of prosumers, energy can be produced and consumed in the same place, in some instances negating the need for distribution. This shift in the energy system means that low carbon transition holds a potential to mitigate energy precariousness experienced in peripheries.

However, this remains an empirical question that needs to be problematized and critically explored rather than taken for granted. Indeed, there are emerging concerns that low-carbon energy transition further articulates inequalities inherited from pre-existing (carbon) systems: different communities experience emergence, deployment, benefits and vulnerabilities with respect to new energy modalities and innovation in uneven ways. Sovacool et al. (2019a) indicate that many of these energy injustices in low carbon transitions remain "invisible" and need to be better understood; based on their interviews with respect of the development of nuclear smart meters, electric vehicles and solar panels in four EU countries, they catalogued "120 distinct injustices" (or socially negative impacts), which principally included concerns over hurting vulnerable groups, externalities, unemployment, unfairness to taxpayers, higher energy prices, and elitism. Many such negative impacts are, arguably, spatially differentiated, disproportionally affecting already vulnerable areas

and communities. Thus, energy continues to be "bound up with the reproduction of uneven patterns of development and access to flows of capital" (Castan Broto and Baker 2018, p. 3). For example, uneven power relations over land and territory shape renewable energy developments (Yenneti et al. 2016) informing ownership, scale, technology in addition to local economic impacts (Hagg et al. 2012; Healy and Barry 2017).

For energy peripheries, characterised by social, economic and political disadvantage and the multitude of wider problematics each brings, low carbon transition can potentially "reflect and reinforce existing power relations" (Gailing 2016, p. 244). We demonstrate this later in the paper too.

3. Wales: a peripheral nation/national periphery?

Below we further develop these conceptual thoughts in conversation with our empirical study in Wales. Compared to other regions in the UK in terms of gross value added (GVA) and employment levels, Wales "languishes at the bottom" (Dickins 2016, para 24; also National Assembly for Wales 2018). While in terms of GDP per capita, the UK as a whole is above the EU average (inclusive of the UK itself) (108%), Wales is only 76% of the EU levels, making it among EU weakest regional economies (Eurostat 2017). The low economic output and high level of unemployment, along with underdeveloped local facilities, poor housing and health that are often associated with Wales are usually attributed to the enduring deindustrialising effects of the decline of Wales's coal and metal industries (Botterill et al. 2000). This is an accurate yet somewhat simplified glance into a multi-century political and economic marginalisation of Wales. In words of Adam Price (2009), an academic turned to become the leader of Plaid Cymru, a Welsh national political party, Wales has been Britain's 'first and final colony': being a key part of the British Empire's global colonial conquest, the Welsh people remained subaltern within the empire. As well expressed by Faletra (2014) in reference to the emergence of particular representations of Wales in literature and historiography ever since the medieval period: "Wales is England's original repressed Others, the unruly subaltern that England sees in its mirror" (p. 1), "barbaric peripheral zone requiring colonial control" (back cover).

While the establishment of the autonomous Welsh Assembly Government (WAG) in 1999 has brought political powers to the people of Wales, the devolution has not been as comprehensive as in Scotland. For example, the Welsh Government has continuously voiced its discontent at constraints over its energy policy, which is seen to limit energy developments in addition to disjointed and cumbersome planning and consenting procedures (Welsh Government 2014; Cowell et al. 2017; Haf et al. 2017). Frustrations also exist about higher energy prices in Wales compared to other UK service regions (The House of Commons Library 2017) despite Wales is a net electricity exporter (Welsh Government 2017a). These struggles do periodically produce concessions from London. For example, the Wales Act 2017 extends Wales's energy policy remit to include the licencing and granting of consent for onshore oil and gas projects; all onshore wind projects and offshore wind projects under 350 MW; other than wind electricity projects under 350MW that are developed onshore and offshore; and the promotion of energy efficiency. Wales have also increased its powers indirectly via the Planning (Wales) Act 2015, the Wellbeing of Future Generations (Wales) Act 2015 and the Environment Act (Wales) 2016, which provide a range of criteria to be satisfied in future developments that include energy.

While UK energy policies have followed the EU targets to reduce carbon dioxide emissions by 80-95% by 2050, there are also concerns around "energy trilemma": balancing energy security, energy equity, and environmental sustainability. In Wales, fuel poverty was historically more pronounced than in other UK regions apart from Northern Ireland. In 2011, then using a common methodology (a more than 10% of household income spent on energy services, nominally determined), the UK Government identified the following proportions of households living in fuel poverty: 15% in

England, 25% in Scotland, 29% in Wales and 42% in Northern Ireland (DECC 2013). The responsibility for addressing and measuring fuel poverty was then devolved and became less comparable, with Wales keeping a 10% measure and England moving in 2013 to the Low Income High Cost – LIHC indicator. In its 2010 Fuel Poverty Strategy (WAG, 2010a) the Welsh Government set a target to eradicate fuel poverty in all households by 2018. A 2016 estimate on the 10% measure suggested that 23% of all households in Wales were still living in fuel poverty in 2016 (Welsh Government 2016). Approaching the 2018 deadline, however, the figure dropped to 12% according to a more thorough and official statistical analysis (Welsh Government, 2019). According to it, Wales has even levelled with England on the LIHC measure: 10% of all households in Wales in 2018 versus 11% of households in England in 2017 and 7% of households in Northern Ireland in 2016.

Fuel poverty in Wales has been addressed via its Fuel Poverty Strategy (2010a) and Warmer Homes schemes Arbed (2009) and Nest (2011), which have aimed to improve housing energy efficiency. However, while reducing domestic energy consumption is consistent with carbon reduction targets, some actions to resolve energy trilemma can be seen as mutually contradictory; for example, the low-carbon policies that reduce reliance on carbon-heavy energy supplies have increased consumers energy bills and, consequently, fuel poverty (Bickerstaff et al. 2013). And yet, while recent UK Government decisions have reduced subsidies for low-carbon renewable energy and increased support for nuclear energy, Wales retains its strong commitment to renewable low-carbon energy. It has set an annual reduction target of 3% on greenhouse gas emissions in areas of devolved competence and at least a 40% reduction in total emissions in Wales by 2020, rising to 70% by 2030 on a 1990 baseline (WAG 2010b; Welsh Government 2017b). There is the ambition "to create a sustainable, low carbon economy for Wales" and to be a world leader in low-carbon renewable energy generation (Welsh Government 2017c).

Such misaligned energy priorities between the UK and Wales can cause friction between Cardiff and London; however, many also see this as a sign of divergence from the traditional "branch office mentality", where people in Wales are perceived to lack confidence. As expressed in one expert interview:

> *[Welsh Government have] not got that flexibility, it's all a bit risk-averse. It's all still a bit of a problem, although things have changed a bit. Maybe that's the way in Wales as well – post-colonialism takes a while to shake it off, doesn't it?* (Expert interview).

This view resonates with common sentiments about the political status of Wales within the UK: as a peripheral nation-region. This reflects both objective and subjective spatial orderings such as in performance indicators; media's continuing representations of Wales as lagging behind (Tannock 2015; Dickins 2016) and even academic definitions of periphery (Keating and Jones 1991; Owen et al. 2000). But core-periphery dynamics is also evident at the intra-region scale within Wales and it is often maintained by domestic institutions. For example, while the total Block Grant[1] from the UK government to all regions has been reduced year on year since 2009/10 (Institute for Fiscal Studies 2016), Welsh rural local authorities have suffered more frequent and higher cuts in the allocation of the Revenue Support Grant[2] by the Welsh Government. Such cuts negatively impact the viability of public services, enhancing peripheralization. The highest levels of GVA per capita within Wales are attributed to urban places, which concentrate employment, capital and value generation, influencing commuting practices within surrounding rural areas. Urban areas of Wales also have the more extensive and reliable energy networks (National Assembly for Wales 2014) and lower levels of energy inefficient houses than rural and peri-urban areas (Centre for Sustainable

[1] Block Grants are the element of the devolved administrations' funding which comes directly from the UK Government. Once the block grant has been determined, the devolved administrations have freedom to make their own spending decisions in areas of devolved responsibilities within the overall totals (H.M. Treasury 2017).

[2] Revenue Support Grants are derived mostly from the block grant and are administered by the Welsh Government to each of the 22 local authorities in Wales.

Energy 2015). The next sections will delve deeper into the interconnection of peripheralization and energy experiences, including how peripheral energy vulnerabilities are implicated in low-carbon energy transition.

4. Peripheral household economy and practices

Peripheralization has wide-ranging implications, affecting the local economy, the socio-demographic mix and the availability of public services. This circular leaching of labour, finance and services has left many places with shrinking populations that are aging, with limited or no services. Public spending cuts along with the sparsity of population means that some settlements no longer have public transport and that for most household personal transport becomes vital for accessing jobs and services. But even in those places that do have public transport, the latter is often infrequent to be suitable to most people's employment times or managing everyday life:

> *You have to have two cars. We are trying to run with one car but when I am out my wife can't leave the home, so she takes me to work to keep the car. And every journey is like a 20-mile round-trip, nothing is near, so we use an enormous amount of fuel* (Mark, homeowner, aged 50-59).

Nearly all our interviewees have noted that a peripherally positioned area incurs a high cost of living – largely attributed to the cost of transport (Chatterton et al. 2018) as well as energy. The lack of public transport and public services adds to feelings of marginalisation:

> *The school is closed, we haven't got a village shop, our chapel's been sold off and has been made into a house and we get a post van up here twice a week, on a Monday and a Thursday for an hour a day. The man that's running it now has offered to bring if we need anything, he'll bring anything that we need up for us – which is making us feel not easy about it but more of an outcast really!* (Megan, social tenant, aged 70+).

The remoteness from core-urban areas also plays a role in creating situations of fuel vulnerability, as more constrained incomes, coupled with high vehicle running costs, contribute to a precarious ability to afford energy. Self-rationing of energy consumption is one of the coping strategies to retain car mobility, since the latter is crucial for living in periphery (cf. Mattioli et al. 2017).

Energy infrastructure reinforces the core-periphery division. Average energy costs for gas and electricity accessed via the central energy network or 'mains' are more expensive in Wales than in the majority of other UK regions (The House of Commons Library 2017). But it is particularly peripheral households that are confined to more expensive sources. Indeed, approximately 46% of rural homes in Wales are still off-gas, compared to 34% in England and 32% in Scotland; most of these homes are heated by oil or LPG (liquid petroleum gas), which are priced higher than mains supplies (Citizens Advice 2017). While most (but not all) homes have access to electricity networks, electricity in the UK has not been widely used for space heating or hot water due to its even higher costs (Energy Saving Trust 2018). All our interviewees highlighted their lack of choice over energy source, resulting in higher energy costs:

> *Living in a rural community is more expensive; people are spending more money on various fuels because of where they live. Yes, it is beautiful, but if you can't afford to turn the heating on, that's not so beautiful. In our old house, we spent a huge amount of money. Huge! We had LPG from a tanker. Whatever you do, it's always expensive* (Jose, homeowner, aged 60-69).

Smith et al. (2010) found that the financial costs of living in a rural home are higher than urban homes in all three of the different rural homes categories they researched. The more remote the house is, the higher the cost of living is, which is attributed to the difference in energy spending between urban and rural locations. So, a working age couple, with two children would need to spend 12% more per week living in a rural town or 18% more per week living in a hamlet than their urban counterparts.

Living off gas suggests reliance on alternative energy technologies. There are types of traditional cooking and heating systems that are often seen as part of the charm or character of rural living, but which reflect inefficient peripheral energy practices. Range cookers such as Agas and Rayburns are such examples; they work on the principles of heat storage whereby they are run continuously by slow burning fuel. Traditionally they comprised ovens and hot plates and burned coal and wood, but they were later developed to use kerosene, diesel, biofuel, gas or electricity and also developed with central heating capabilities within a house. Their use of hard fuels means they are considered appropriate for homes without electricity and/or natural gas connection. However, the energy efficiency of such traditional range cookers is poor; they can use over 30 times more energy for cooking than the UK average (Lightfoot Energy Service 2018). Nevertheless, the cost of changing to a new modern range cooker or an alternative cooker and heating system is prohibitive to most households. Our interviewees have noted energy coping practices specific to peripheral places; for example, the use of range cookers continuously generates heat and householders reduce excessive temperatures by opening windows and doors.

Non-mains energy supply means security of supply can be problematic too. For example, households using traditional carbon-heavy fuels such as oil must monitor their consumption and order replenishment in good time. The factor of weather and whether fuel deliveries can physically reach the buildings is specific to such locations:

> *It is a real risk because we do prepare to be snowed in, because it could very easily happen. It's a one-track road so I can't imagine anyone is getting in whatsoever. So we do make sure we've got stuff in for the dogs and we've got a little gas burner so we won't be relying on electricity… In the winter you have to think of [oil deliveries] in advance because there's no point letting your fuel run down and then they can't get to you* (Michael, homeowner, aged 45-64).

Physically poor electricity infrastructure in rural peripheries means that those networks are also less resilient to adverse weather conditions. As Michael's comment above highlights, for households in places without mains gas consideration has to be given to alternative sources of both heat and electricity at these times. For example, in February and March 2018, when the daytime temperatures fell to -4 °C, "some rural communities were entirely cut-off and had to receive supplies by helicopter" (National Energy Action 2018, p. 5).

Another source of technological vulnerabilities is the type of buildings. Building structure, size, age and state of repair affect the level of energy required to make a home comfortable and meet personal needs. Our interviewees lived in a range of building structures and types, including detached, semi-detached, terrace homes and flats, with solid stonewalls, timbre frame, brick and non-standard construction. However, the majority were pre-1900 solid stonewall builds, which are particularly difficult to keep warm and insulate. This type is characteristic to peripheral areas in Wales and, furthermore, in conservation areas it is protected to maintain the traditional character of the area. However, such "leaky" homes create various problems for living conditions even besides energy:

> *It was just damp throughout the whole place. And it's not even something in the walls and stuff, it's in the air. It's the moisture in the air, so it gets on all of your stuff and things, and the bedding smells crap!* (Noel, private renter, aged 30-39).

It is evident that households in peripheral places, even when not classified officially as 'fuel poor', experience end-use energy vulnerability in multiple ways. In a broader sense, energy precarity emerges as a hidden condition in the convoluted web of social vulnerabilities, differentiated spatially due to uneven distributions of economic, political and social power. These energo-social vulnerabilities are highly connected to spatial peripheralization processes and outcomes, which means they are embedded within the development of peripheral places or necessitated by living within the periphery.

Table 2 adopts the energy vulnerability factors such as those outlined by Simcock and Petrova (2017, p. 432) and other authors and identifies both social and spatial contingency of each of the factor. Each factor of energy vulnerability holds a spatial contingency experienced by our interviewees in peripheral Wales. While energy vulnerability work tends to focus on individuals or groups of individuals, a place-based perspective offered in this paper recognises the co-constitution of spatial and energy vulnerabilities. For example, what differentiates energy peripheries from other places such as core urban settings is that many of the vulnerabilities experienced within energy peripheries can be linked back directly to their spatio-structural disadvantages. Such disadvantages impact many aspects of peripheral life in addition to aspects of energy more generally. For instance, in a UK setting it is unlikely that even an urban periphery will experience a lack of access to the mains energy grid, including gas grid; in this way they also avoid the greater costs associated with accessing non-mains energy. To sum up, the occurrence of the more generic vulnerabilities in a peripheral context mounts up with other socio-economic vulnerabilities, so that their effect becomes compound, creating a landscape of precariousness specific to peripherality.

Vulnerability factors	**Social contingency**	**Spatial contingency**
Availability	Energy sufficient to meet energy demand and provide satisfactory living conditions	Grid and off-grid locations; varied energy mix available in different places; exclusionary spatial practices of providers
Affordability	Disposable income in relation to the cost of energy services and to the cost of domestic energy improvements	Spatially segregated incomes and differentiated costs of living; subsidies, social housing; off-grid and remoteness increase energy-related expenditures
Reliability	Certainties and security of energy provision and energy services	Place-specific hazards (natural, anthropogenic); varied quality and resilience of existing energy systems
Dependency	Ability to switch providers, change fuel mix, make energy improvements, control energy use	Reliance on locally-feasible energy systems and practices; conservative built environment and energy infrastructure; restrictive local regulation
Efficiency	Energy efficiency of housing, infrastructure, appliances, and settlements.	Place-specific energy standards of the built environment and infrastructure; built forms; spatially determined mobility patterns
Necessity	Household energy needs from private circumstances and demography	Spatial concentration of vulnerable groups; location-specific household energy requirements; different climatic conditions
Subjectivity	Energy behaviours and socio-cultural norms; knowledge about energy systems; private acceptance of energy modifications	Place-specific energy consumption tactics and norms; local conventions; community acceptance of energy projects; community solidarity

Table 2. Socio-spatial contingencies of end-use energy vulnerability

5. Transition for all or fragmented inclusivity?

Low-carbon energy transition is unfolding within this uneven context. Our research demonstrates that the mode of transition and who is able to take it forward is in large part economically contingent, which in turn for most households is spatially contingent too. The relative high cost of change combined with an already high cost of living means that although for example there are aspirations to install renewable and energy efficient technology and recognition that it would be cost-saving for the household in the long-run, it is not possible financially.

There is a variety of policy schemes that are deployed in Wales to encourage household energy transition. For example, a lack of access to mains-gas network makes low-carbon heating more

attractive; as low-carbon heat generation is expensive to install, the Domestic Renewable Heat Incentive (RHI) was set up by the UK Government in 2014 to mitigate some of these costs by paying for energy generated over a seven-year period. While not limited to non-gas network homes, the scheme is particularly aimed at them and is unlikely to be economical otherwise. Alternatively, households with access to the mains electricity grid can participate in the UK Government Feed-in-Tariff scheme (FIT) whereby payment is made to the producer for energy exported to the National Grid in addition to payments for the total energy generated (even if consumed by the household). In this case, having access to mains electricity networks and generating electricity, as opposed to, or in addition to heat generation, is of greater benefit – especially for those who adopted FIT at time when it set generous payback conditions:

> *I genuinely feel since having the solar panels we don't spend as much on oil…. We both work from home. I've got two computers on all the time. I've got the telly on; the lights are on. In the summer, we'll get back per month about £200 on top of our free electricity* (Lydia, homeowner, aged 50-59).

For those who can participate in such schemes, end-use energy vulnerabilities can be alleviated; for example, renewable generation can reduce reliance on expensive sources such as oil. This has a double effect of providing a more secure energy source: it is directly connected to the home (as opposed to being delivered by a truck) and it is of a lower cost. However, this mode of transition is restricted to those with agency over the building and finance to change the said building's energy system, thus it is often restricted to wealthier homeowners (e.g. Bickerstaff et al. 2013; Sovacool et al. 2019b). Even in the case that Registered Social Landlords are installing transition measures to socially tenanted properties, tenants benefit from lower energy bills (if the technology is installed and used correctly) but the landlord benefits from any FIT or RHI received.

From this perspective, housing energy efficiency is potentially a more inclusive dimension of energy transition (Golubchikov 2009), although reservations over inequalities are still applicable. Most of our interviewees had some form of energy efficiency measures. This can include energy-saving light, loft insulation, internal wall insulation, cavity wall insulation as well as double-glazing. However, for many households, deep retrofit is unachievable due to the physical building structure and/or the costs involved. For example, for pre-1900 solid stone wall houses typical in peripheral Wales, loft insulation is usually viable, as is double glazing (as long as the house is located outside a government-designated conservation area), but additional insulation to walls is limited to internal or external cladding, which many consider to be too expensive or disruptive. Internal cladding causes disruption and requires re-decoration, while external cladding changes the look of the exterior, so it is only suitable to non-conservation areas. Yet, while these energy efficiency retrofits are expensive, both social tenants and homeowners praise the benefits when they are achieved in practice:

> *The year before last they put the external cladding on. It's the best thing they did. I've moved the room around since then because I couldn't put the chair by the window before because of the draught, but I can now […] The insulation has made a massive difference. Normally by this time, I'd have to put more oil in again but I have half a tank left now* (Olive, social tenant, aged 70+).

It is positive that a number of socially rented homes and low-income households have participated in energy efficiency schemes thanks to policy protections in the Welsh Housing Quality Standard (WHQS) (2002) and the Arbed area-based energy efficiency scheme. This makes the benefits of energy transition more inclusive. However, area-based schemes typically target areas where it is perceived that highest numbers of socially rented and economically deprived homes are located. The sparsity of rural populations, combined with lower numbers of socially rented homes and a reliance by administrators on area-based measures of deprivation (which 'hide' rural deprivation) means rural peripheries are more often overlooked.

Overall, homeowners on lower incomes or with higher living expenses and privately rented households are least able to either generate renewable energy or increase their homes' energy

efficiency; for private tenants this is due to their lack of ownership, and for owned homes this is mostly due to the financial cost:

> *You're stuck and that is where you're getting hit the hardest from everywhere. So it is the case of we'd like to do more, but we can't, and we're not poor enough to get help. But yet you're still sort of living hand to mouth sometimes, waiting to get paid just to get things done* (Joan, homeowner, aged 40-49).

Besides household-level technologies, energy transition also brings larger scale renewable projects to peripheries. Here, the lack of investment in public services contrasts with investment in renewable energy projects that are increasingly located in such locations due to their political convenience as "industries and government seek the path of least resistance to development". Schlosberg (2013, p. 39). The Welsh Government's Technical Advice Note 8: Renewable Energy (2005) identifies seven Strategic Search Areas (SSAs) for renewable energy generation; two SSA's were within or close to our study locations and had commercial wind farm developments. Many households find these developments to be 'undemocratic'; they feel powerless in influencing what happens in their local area and disassociate themselves from any benefits that arise:

> *We've had up all the hassle with the wind turbine farms, with the transport, but that all gets piped away, we're not even getting the electric out of it. You wouldn't mind if you had the benefits, because I'm a supporter of windfarms. But you would like some of the benefits of it as well. Why it all has to go to England I don't know. Hundreds of pylons we're going to have, to carry the electricity and that spoils our quality of life* (Mark, social tenant, aged 45-64).

While larger energy developments could provide local benefits, our interviews demonstrate that from an end-use perspective they are perceived to be undemocratically undertaken with outcomes misaligned with local needs. This is in line with other studies that point out that areas with sparse populations, low incomes and low political power constitute communities with little capacity to assert themselves in non-domestic energy generation discussions (Bristow et al. 2012). While larger non-domestic renewable energy generation is often portrayed as a vehicle to reduce end-use energy vulnerabilities in peripheral places, evidence suggests that the reality may be more problematic, if not exacerbating pre-existing vulnerabilities and creating new inequalities (Yenneti et al. 2016). Indeed, links were constantly made by our interviewees between physical remoteness, feeling politically unrepresented and missing out on investments that could potentially improve declining local services and employment levels:

> *We do feel that, the further North you go, the more you're forgotten about in Cardiff […] because there's no investment around here, none at all. It's very poor, very poor. But we're very good for cuts, if there's going to be cuts, then we'll get the cuts* (Marie, social tenant, aged 45-64).

In short, the low-carbon energy transition in the UK is unfolding in an already uneven landscape of core and periphery reinforced through a multitude of spatial, social and material mechanisms, through a landscape that favours agglomeration and growth. Through historic physical distribution networks and the monetary value of energy itself, access to energy can replicate and further reinforce this uneven landscape. Who can participate in energy transition, how, where and to what effect is highly variable and, importantly for the purpose of our consideration, spatially contingent.

6. Conclusions

We have used the notion of energy periphery to interrogate the interplay of uneven development and energy vulnerabilities at a regional scale, focusing in particular on end-use vulnerabilities. Our central argument is that the processes of geographical peripheralization matter much for intensifying energy precarity, to the extent that one can identify energy periphery as a particular spatial form of energo-social vulnerabilities. The paper consequently bridges the analytical lens of

uneven development and that of energy vulnerability/justice to discuss key factors that stand behind the production of energy periphery. This includes factors of political marginalisation, socio-economic and material conditions, public service provision, as well as conditions underpinning the availability, accessibility, affordability and sensibilities of energy practices and experiences. While energy periphery encompasses the energy vulnerability concept, it is still broader than the latter; it employs more explicitly the concept of uneven development to recognise the exigencies of the capitalist system (e.g. agglomeration, growth, efficiency and inequalities) that favour the core over the periphery.

The so-called low-carbon transition further illuminates injustices inherent in the current energy system and how they can persist. Low carbon transition can potentially be a mechanism for change and decentralising physical energy systems and markets. However, as it is operating under the same forces that prioritise the core, it hardly addresses structural weaknesses of these places. Out of the various options that energy transition brings, energy efficiency improvements and household-level installations appear to be most inclusive. Even so, they benefit a small range of households in peripheries, but most households remain locked-in to outdated, inefficient and carbon heavy technologies. As spatial justice calls for the "fair and equitable distribution in space of socially valued resources and the opportunity to use them" (Soja 2009, p. 3) this is a sign of injustice, leaving energy peripheries with a little say in what technologies are pursued, in what locations, and what impacts there may be on local landscapes and economies.

A broader implication is that different communities and places (and not only social groups) experience emergence, deployment, benefits and vulnerabilities with respect to new energy modalities and innovation in fundamentally uneven ways. The resolution of this dilemma seems to be lying not so much in the technological advancement of transition or distributed modalities of renewable installations *per se*, but rather more deeply in reforming institutional settings for active *de*-peripheralization, that is, addressing the peripheral circumstances in their entirety, including (but not limited to) integrating spatial justice considerations through energy system decisions.

Finally, while Wales is considered to be a developed country as part of the Global North and thus with different energy concerns to developing countries, peripheral energy vulnerabilities and the limits to transitional opportunities connect peripheries internationally by their similar socio-economic positions relative to their cores (Hernandez 2015). Thus, conceptualizing energy periphery acts to illuminate how and why peripheries due to their multiple inherent disadvantages are at higher risk of exploitation during energy generation, marginalisation during energy distribution and precariousness in energy consumption.

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